Using Assigned but Unlicensed Spectrum (Float)
to Provide High Bandwidth Communication Services to Rural Areas

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Abstract:
The dearth of high-speed communications in rural areas contrasts sharply with the possibly abundant supply of unused radio spectrum in the same geographic region. Wired high-speed communications services were not designed for use in sparsely populated areas and consequently have not been significantly deployed to those areas. This paper proposes a novel method of utilizing assigned but unlicensed spectrum (float spectrum) to provide high-speed communications to rural areas. An Interference Generation Mitigation? radio is proposed to utilize float spectrum for use in a Rural Area Network? .

Background:
Spectrum is the most precious of resources, if it is not used for any fraction of a second it is lost, and it is never consumed by its use.

In the United States, the Federal Communications Commission (FCC) is responsible for controlling commercial use of spectrum and the National Telecommunications and Information Administration (NTIA) has this responsibility for the government's use of spectrum. Currently the FCC assigns blocks of frequencies for a specific type of use in band and then licenses a part of these bands to users as channels. Historically the users have not had to pay for spectrum. If there was only one applicant for a specific license then they were awarded the license. When there were several applicants for a specific license the FCC would hold competitive hearings, and eventually the party deemed as most suitable to "operate in the public interest" received the license. This often protracted process became known as a "Beauty Contest".

In 1982 the FCC was authorized by Congress with legislation to use a lottery system to assign licenses.[1] The lottery award system lasted for over a decade until it was replaced by an auction-based award process by the Omnibus Budget Reconciliation Act of 1993.[2] The auction method has persisted and has spread from telecommunications spectrum to even media broadcast (TV and radio) and satellite.[3] By being licensed, one is guaranteed the exclusive right to a channel in a geographic region. The owner also has obligations placed on them by the FCC, both technical and policy-based.

There is also additional spectrum that is declared unlicensed. Compared to licensed spectrum, it generally has lower quality of service (QoS) and higher user obligations.[4] The user is not guaranteed exclusive use, and confining limits are placed on transmission power, transmission method, and usage etiquette.[5] In reality very little spectrum is unlicensed, but the amount in this category has significantly increased. Until recently the only unlicensed spectrum used for advanced telecommunications was the 2.4 GHz Industrial, Scientific, and Medical band (ISM), but now there is the Unlicensed National Information Infrastructure (UNII) which is a 300 MHz noncontiguous band between 5.15 GHz and 5.825 GHz, the Unlicensed Personal Communications Service (UPCS) which offers 30 MHz of bandwidth, and the 59-64 GHz Millimeter Wave band.[5,6] These new unlicensed bands have different QoS and obligations (not necessarily higher or more lenient), but they do have the distinct disadvantage of requiring higher frequency equipment. Because of this, nearly all users (i.e. HomeRF, 802.11b, BlueTooth, Ricochet, RoofTop) of these unlicensed bands currently operate in the 2.4 GHz ISM band.[7,8,9] It is evident that the 2.4 GHz ISM will soon be saturated with users, even when employing the most advanced digital signal processing techniques.[4]

Current users of the licensed and unlicensed band have significantly different needs. Licensed broadcast media and telecommunications represent the traditional users of spectrum. They require permanent channel assignment and low interference to best serve their customers. Unlicensed users are

Spectrum Operation Environment

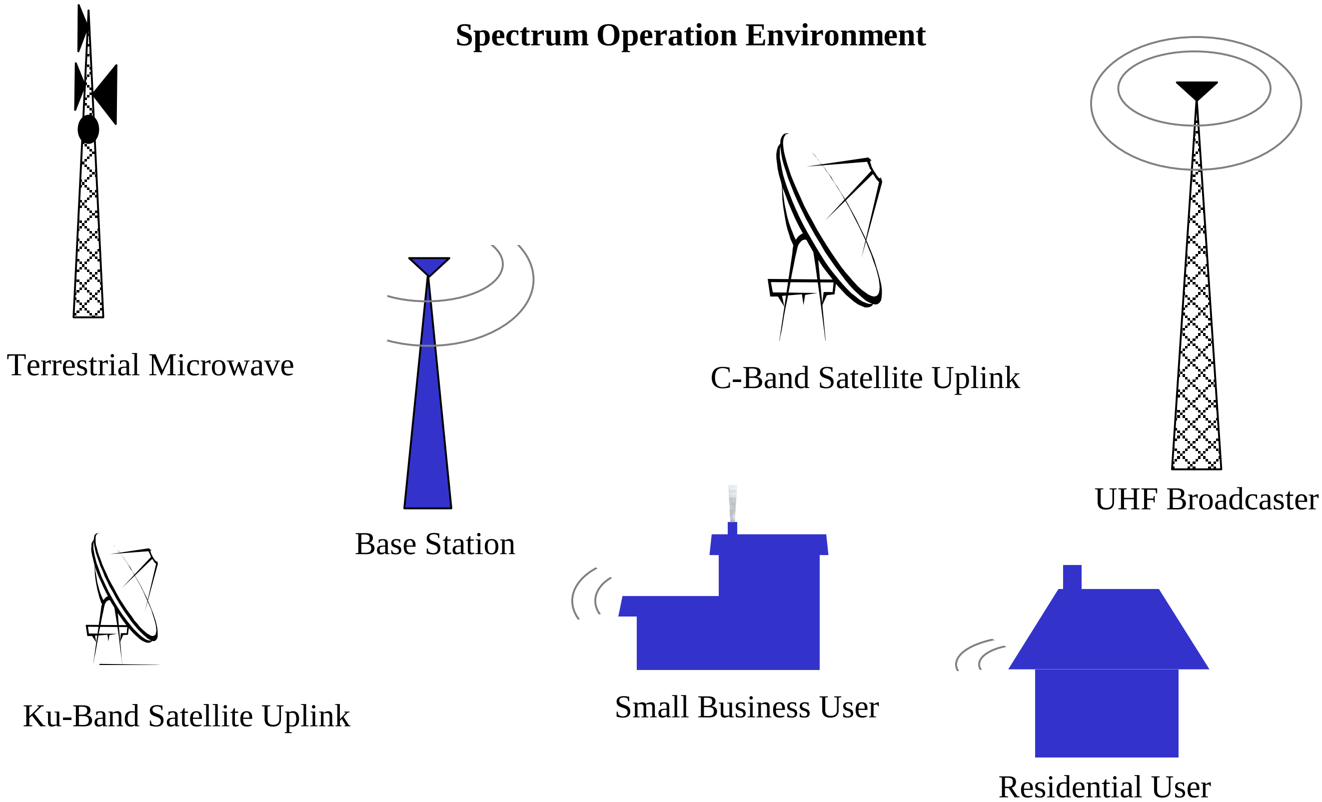


Figure 1

Blue shading denotes components of Interference Generation Mitigation? system.

currently confined to wireless local area computer networks or pico area networks. These users require universal geographic access to spectrum without previously being granted a license to use it. Reduction in quality of service is a compromise they accept since there are few alternatives and usage is of a convenience nature (rarely mission critical).

In general, the banding of frequencies for licensed and unlicensed channels allows for standardized media and telecommunications uses. This allows for TV, radio, terrestrial microwave, terrestrial cellular, satellite communications, radio navigation and wireless networks to have fixed frequency ranges, regardless of locality. The main benefit of this is lower cost equipment and interoperability.[4]

Float Spectrum Defined:

It is important to understand that even though spectrum *bands* are assigned, often not all the *channels* in the band are licensed. Even in a major television market, no viewer will find all channels 2 thru 69 active. This is not only because there are too few prospective licensees, but also to maintain a separation distance between stations operating on the same channel. The same is true for other spectrum bands. Portions of the spectrum where there are no operating licensees constitutes float spectrum. An example of this is beyond the grade B reception contour of a TV station; thus float spectrum includes not only unlicensed spectrum but also the buffer zones. An analogy to spectrum float is the money float at a bank: when a bank removes money from one account and places in another there is a short transfer time, for a large bank this continuous money in flux is quite significant and a source of money to loan out.

Another example of current float is the NextWave cellular licenses, whose ownership is in dispute. In 1996 NextWave purchased more than 200 cellular license, including licenses in such major markets as New York, Chicago and Los Angeles, for $4.74 billion. The company, now bankrupt, has paid only 10% of what it owes for the licenses and has never established mobile wireless service with them. For the past several years the FCC and NextWave have battled over ownership of the licenses, while the

Customer Premises Equipment (CPE) Block Diagram

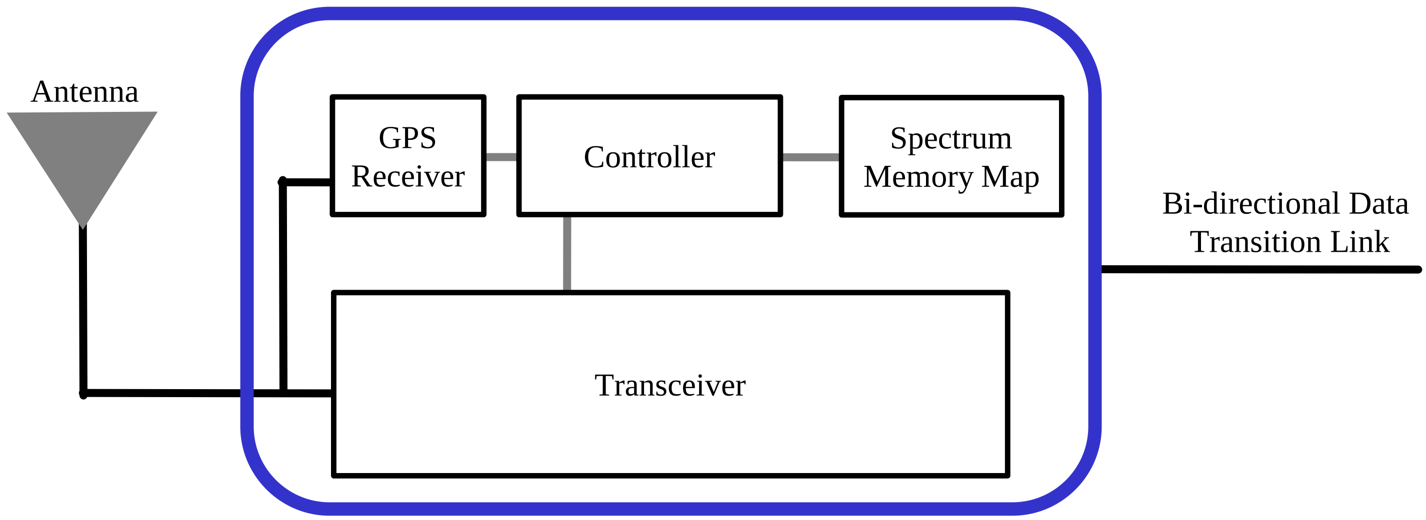


Figure 2

desirable (float) spectrum goes unused.[10]

Considerable float does exist. Reports by the U.S. Dept. of Commerce show significant unused spectrum in urban areas, and in rural areas a dearth of spectrum users.[11,12]

A method could be devised to provide the float on a temporary basis to users while having no negative externalities to current or future licensees.

In the past, hardware limitations would have made exploitation of float spectrum quite difficult, but broadband radio exist that can use this scattering of frequencies have been recently demonstrated, including software-based radios which can tune from 2 MHz to 2 GHz.[13,14,15]

From a system provider standpoint float will offer QoS and obligations somewhere between the unlicensed and licensed spectra. Authority to use float spectrum will be granted by the FCC in a manner similar to the licensing process. This permit will provide the use of float spectrum with significant bandwidth, maximum emitted power and usage dwell times to fit the needs of a large percentage of current users of spectrum who are sub-optimally serviced by the current system.

The Implementation Method:
In using float spectrum the paramount goal is to be imperceptible to the licensed users. One approach to this a thoroughly conceived spectrum management system is the Interference Generation Mitigation? (IGM?) model, described below.

Figure 1 presents the typical operational environment that a wireless terrestrial communication system using float spectrum would encounter. Present licensees emitting power at varying frequencies in many possible directions over a terrain and through an atmosphere that alters the propagation of the radio waves. In addition to this, the environment varies over time: transmitters are turned on and off, the ionosphere's charge density changes over the course of the day (this is why AM radio station must reduce their transmit power at night), and the geographical terrain gets modified by man and nature (leaves fall, and buildings are constructed).[16] A 'low tier' approach is used which takes all these parameters into account.

Example of a Minimum Power Flux Density Mask for Operation

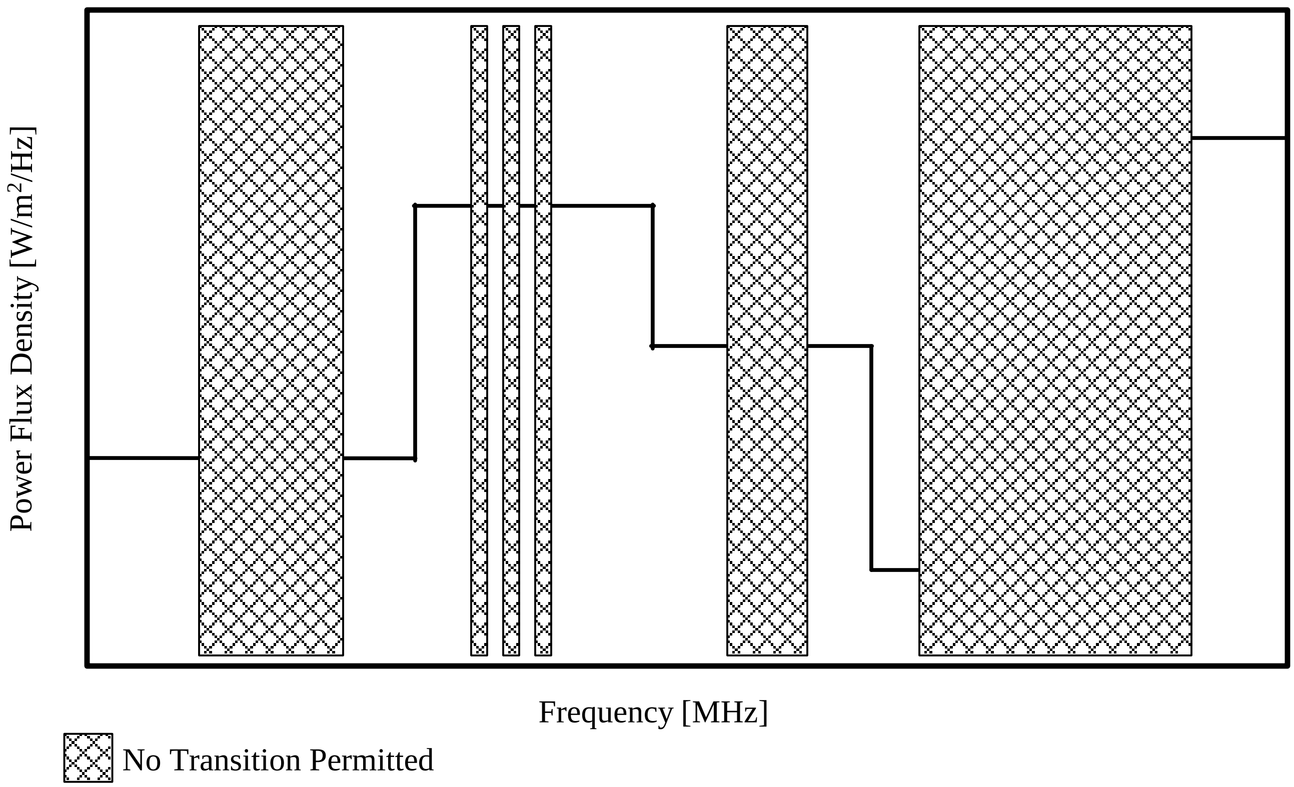
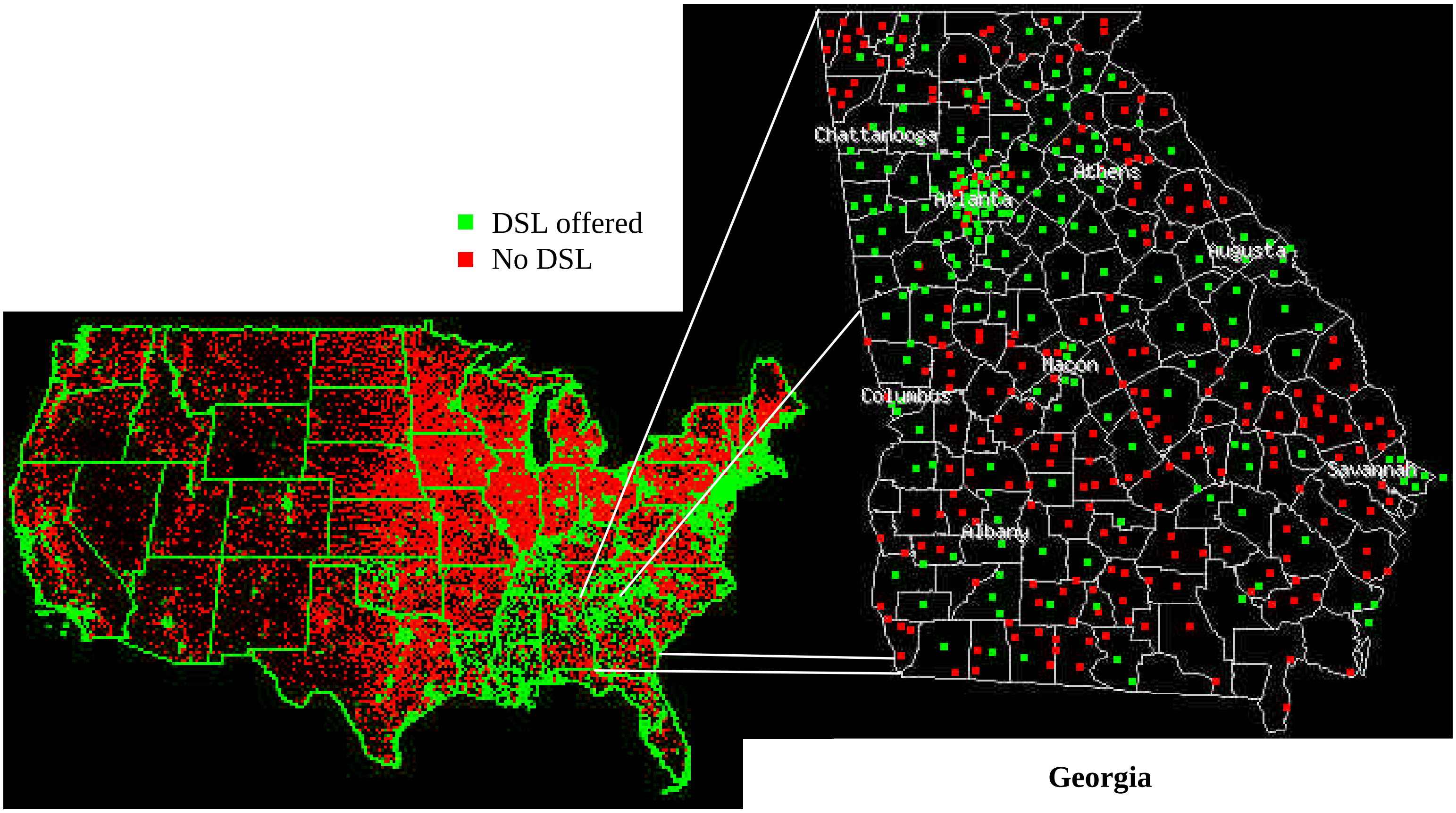


Figure 3

Figure 2 illustrates the block diagram for Customer Premises Equipment (CPE) that this system will utilize. This device, in combination with a base station mounted on a tower, would comprise the IGM? system. When the CPE is first activated, it would determine its geographic location by using the Global Positioning System (GPS); this also allows the CPE to know the precise time (useful for the transmission method). Next the CPE will sweep the range of potential operating frequencies, measuring the power flux density (PFD) a common unit that corresponds to radio field power. The data from this spectrum survey is used to determine frequencies that are unused. Subsequently the CPE will look for the control channel from a base station. When this channel is found, the CPE will compare results of its spectrum search with a list of available channels broadcast by the base station to find a channel that both it and the base station have approved for use. With a communication channel now selected, the CPE will send its location and spectrum survey data to the base station. The base station then takes the data from this CPE and the other CPE's operating in the area along with spectrum surveys it has performed, knowledge of the limitations of the detecting equipment, a terrestrial map of the area, past spectral knowledge of that area, known licensees in that area, and an up-to-date knowledge of transmitting restrictions to allocate the CPE frequencies and transmitting method that **will cause no perceivable interference to licensed users.**

Figure 3 shows an example one of the tools that the base station can use to prevent disturbing licensed users. The mask in this figure shows the conservatively set minimum PFD levels which can cause harmful interference to the licensed user in the locality of the base station. When the PFD created by the base station or CPE falls below this value, the communication is permitted.

Location of Central Offices



Georgia

United States

Figure 4 [19]
Data current as of November 2001

Since spectral occupancy varies with time due to usage patterns and propagations variability, the system using float spectrum will check several times per second to see if the environment has changed, necessitating it to cease using that frequency channel. This would be done in a brief fraction of a second to prevent disrupting the licensed user.

High Bandwidth Communications in Rural Areas:
A significant portion of the U.S. population lacks access to high bandwidth communication services, which are needed to fully utilize the Internet. This problem is most pronounced in rural areas: 96% of the most densely populated zip codes have users of high speed data service (200 kbps or higher bi-directional as defined by the FCC) compared to 40% for the least densely populated zip codes.[17]

A significant reason for the dramatically lower availability of high bandwidth communications services in rural areas is the lack of existing communications infrastructure on which to deploy high speed services. Digital subscriber line (DSL) is the most popular high bandwidth data service being deployed by local exchange carriers (LEC). DSL utilizes a customer’s existing landline (phone line), but requires that the subscriber be close to their central office (CO). The total length of the phone line between user and CO must not exceed 5.5 km for most LEC to provide service.[18] Figure 4 shows the location of CO’s for the US and Georgia from a independent web-based database.[19] Even when this distance requirement is satisfied, a physical test of the line may show it unable to support DSL.

Cable Modem Deployment in the United States

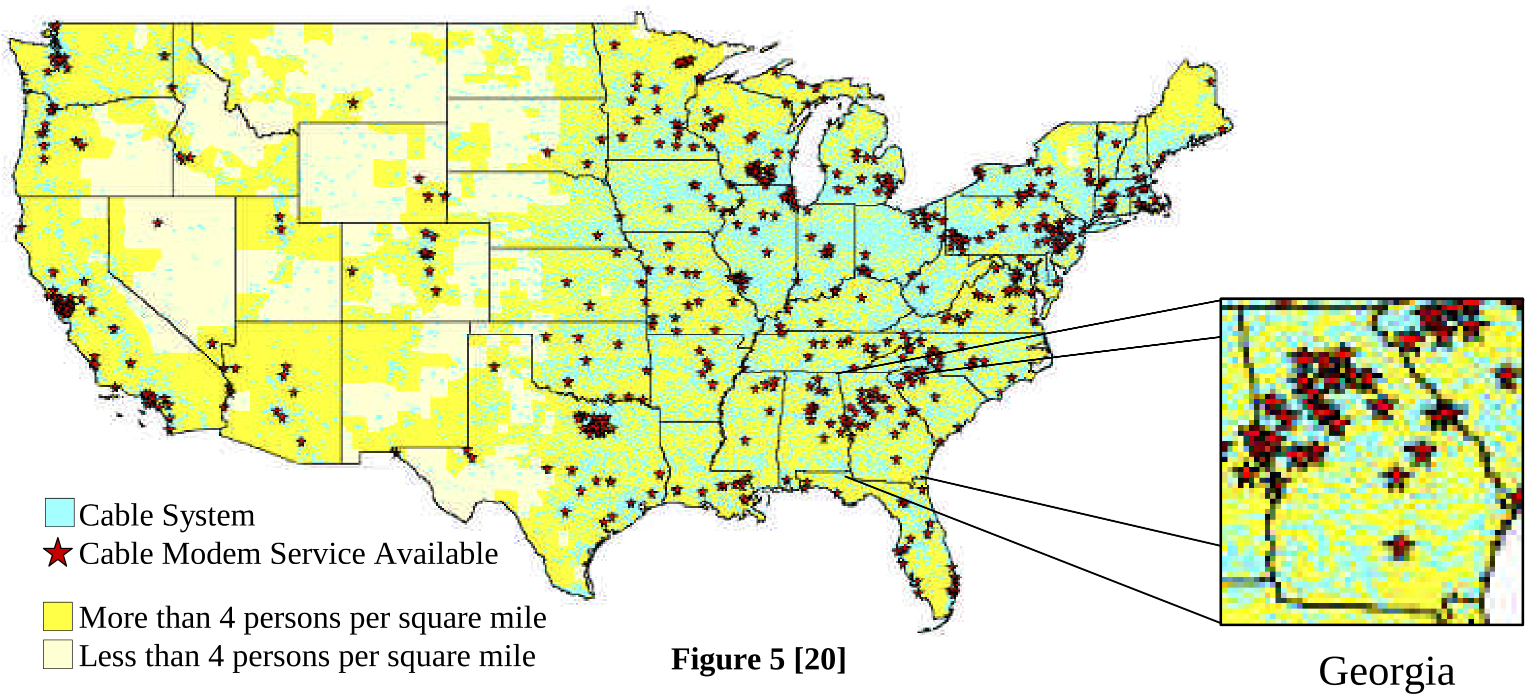


Figure 5 [20]

Cable TV-based high bandwidth communications services require coaxial cable to the user, but rural areas often lack existing cable systems as shown in Figure 5. In less densely populated areas, the cost of building a cable system is often not economical.

Satellite based high-speed data service requires little or no existing infrastructure. DirecWay (formally known as DirecPC) and StarBand are most popular satellite based high-speed Internet access system for consumer users. These systems require high cost user equipment, and cost twice as much per month as DSL or cable modem service of comparable speed.

Fixed wireless high bandwidth communications systems are ideal for Rural Area Network? (RAN?) use. The long distance between the user and the communications carrier's office does not significantly increase system cost, as it does with DSL and cable systems. The most popular fixed wireless system for high-speed communication services to users is local multipoint distribution service (LMDS).[21] This system uses very high Ka-band frequencies, which requires high cost terminal equipment and line-of-sight between user and system antennas. LMDS also suffers from Ka-band's rain fade, which degrades service. Due to these limitations, LMDS has not been widely deployed. LMDS is usually used in densely populated areas as an alterative to wire line service. Multichannel Multipoint Distribution Service (MMDS), which operates at 2.5 GHz does not suffer from rain fade and can operate without line-of-sight. Recently the FCC ruled to allow the MMDS spectrum to be used for 3rd generation mobile wireless networks (3G). Since high-speed fixed wireless offers lower revenue-per-MHz than mobile wireless, there is not a realistic probability that this spectrum could be used for RAN? .

Fixed wireless systems are ideal for providing high bandwidth communication service to rural areas, if frequencies can be used that propagate well and do not require high cost terminal equipment. Float spectrum can provide these frequencies. Since rural areas have few channel licensees, vast quantities of float exist to provide communication services. Rural wireless network systems can be designed and implemented to exploit existing wireless standards and equipment, reducing cost and time to market.[22]

Policy Aspects:

Implementation of communication services based on float spectrum requires re-examination of current regulations to insure that current spectrum users are not affected by the leasing of float spectrum. The licensed holders of spectrum must remain unfettered; retaining the usage rights they have now. Regulations must also provide access to float spectrum that is sufficient in size, transmitted power, and lease time, to be usable. A framework also needs to be developed so that the users of float spectrum can have a viable economic model to justify the investing of capital for infrastructure development.

This will require a new approach to regulations of spectrum access. The customary manner in which the FCC functions involve generating rules and regulations and then opening rulemaking an external party requests change. For radio spectrum, the concerned stakeholders include telecommunications companies, equipment suppliers, and amateur users. The process they pursue to receive access to radio spectrum, or change the regulations of its use, involves a lengthy commitment of their resources with the possibility that their request will be denied.

With the increasing need for spectrum, there could be significant benefit if the FCC could change its approach to a proactive management style. This would transform the role of the Commission to one of a supplier of radio spectrum with the goal of providing the most value to the American people for their national resource. Proactive management either by the Commission or by its licensees would involve being acutely aware of the current levels of spectrum usage, knowledge of the needs of the marketplace both present and future, and taking the initiative in spectrum development. Implementing float spectrum could be the start of a proactive approach to develop spectrum policy.

Conclusion:

Utilizing float spectrum for rural wireless high bandwidth communication systems has the potential to provide Internet access to a significant percentage of the population at lower cost than the alternatives, but will require significant study and development.

This white paper has identified an important area to enhance the use of spectrum for rural areas. Future papers in this series will expand this topic with study, modeling, and measurement of the current spectrum usage in rural Georgia to determine the nature and potential utility of underused spectrum. Specifically, measurement of the actual spectrum usage, especially in rural areas, and quantization of the float spectrum resources must be conducted. Subsequently, design of low cost broadband software-adaptable radio equipment for high-speed Internet access in rural areas must be pursued. Finally a demonstration project will show that float spectrum can be used without causing direct harm to current licensees as well as to unlicensed passive users such as Radio Astronomy Services and Earth Environmental Satellite Services should be conducted.

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